How Accurate Are Pediatric Emergency Tapes? A Comparison of 4 Emergency Tapes With Different Length-Based Weight Categorization

Both, Christian P ; Schmitz, Achim ; Buehler, Philipp K ; Weiss, Markus ; Schmidt, Alexander R

Abstract: OBJECTIVE: Pediatric emergency tapes have been developed to support paramedics and emergency physicians when dosing drugs and selecting medical equipment in pediatric emergency situations. The aim of this study was to compare the accuracy of 4 pediatric emergency tapes to correctly estimate patient's weight based on a large population of patients. METHODS: Patients undergoing general anesthesia between January 2012 and March 2015 with documented age, sex, body weight, and length were identified from the electronic anesthesia patient data management system of the Department of Anaesthesia, University Children's Hospital, Zurich, Switzerland. Weight estimation by means of the Broselow-Tape, the Pädiatrisches Notfalllineal, the Paulino System, and the Kinder-Sicher were compared with true patient's weight. Percentages of estimated body weight within a ±10% and ±20% interval were calculated. Data are median (interquartile range) or count (percent); statistical calculations were done with McNemar and Bonferroni correction. RESULTS: A total of 3307 patients were identified with complete data sets, 1930 (58.4%) were male, median age was 4.1 years (1.1-8.2 years), median length 101.0 cm (74.0-126.0 cm) and median patient weight 15.8 kg (9.2-25.0 kg). The proportion weight estimation within the ±10% and the ±20% interval was the highest in the Broselow-Tape with 54.0% and 81.5% ($P < 0.001$ and $P = 0.003$), followed by the Pädiatrisches Notfalllineal (50.5% and 79.8%), Paulino System (49.9% and 78.0%) and Kinder-Sicher (48.2% and 77.5%). CONCLUSIONS: The overall accuracy of all 4 emergency tapes tested is poor and including a larger number of weight categories does not necessarily increase accuracy. Other strategies have to be developed to improve weight estimation in pediatric emergency situations.

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Conclusions: The overall accuracy of all 4 emergency tapes tested is poor and including a larger number of weight categories does not necessarily increase accuracy. Other strategies have to be developed to improve weight estimation in pediatric emergency situations.

Key Words: body weights and measures, treatment, prehospital care

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Pediatric emergency tapes have been developed to support paramedics and emergency physicians when dosing drugs and selecting medical equipment in pediatric emergency situations. In these situations, the necessary information about age and weight is often not available[1–5] and thus correct drug dosing[1,2,6–8] and the selection of adequately sized medical equipment is difficult or even impossible.[9]

To date, several pediatric emergency tapes are available on the market. They all utilize length-based weight categories, and based on these weight categories, the amount of a certain drug and the size of medical equipment are indicated. The length-based weight categories considerably differ between pediatric emergency tapes.

The aim of this comparative study was to investigate the accuracy of 4 pediatric emergency tapes to estimate patient's weight using a historical patient population.

METHODS

After approval by the local ethics committee of Zurich, Switzerland (KEK-ZH-Nr. 2016–00188), patients with general anesthesia, tracheal intubation, or laryngeal mask insertion, as well as with available information about age, sex, body weight, and length, were retrospectively identified from the electronic anesthesia patient data management system (PDMS, deioRecorder, deioWarehouse, and deioAnalyzer; Datex-Ohmeda, Helsinki, Finland), of the Department of Anaesthesia, University Children's Hospital Zurich. The period assessed was January 2012 to March 2015.

The following 4 pediatric emergency tapes were included in the evaluation (Fig. 1):

- The Broselow Tape (BT; Vital Signs, Inc, Totowa, NJ) is the most frequently used and best investigated pediatric emergency tape.[10–12] It is applicable for patients between 46.6 to 143.2 cm body length, grouped in 26 different categories (from 3.0 to 36.0 kg) for weight estimation. Dose recommendation of various emergency drugs, however, are only based on 9 color-coded zones. Each color-coded zone has 1 corresponding weight, except for the gray zone, which is split into 3 subzones (3.0 kg, 4.0 kg, and 5.0 kg), resulting in a total of 11 weight groups.
- The Pädiatrisches Notfalllineal (PNL; Alpha 1 Werbedesign e.K., Falkenberg, Germany) is a pediatric emergency tape certified for clinical use in Europe[13–16] and applicable for a body length from 44 to 140 cm using 11 length-based weight categories. On the emergency tape itself, dosing for several emergency drugs, sizes of medical equipment, and values for vital sign parameters are suggested for each of the 11 categories.
- The Kinder-Sicher (KS; T.O. Zugck, Heide, Germany) consists of the ruler "Pediatape" (www.pediatape.com) and a booklet. The ruler estimates patient weight divided in 11 weight categories. A booklet provides for each of these 11 categories a recommendation for drug dosing, sizes of medical equipment, and vital parameters for patients between 46.8 and 143.3 cm body length.
- The Paulino System (PS; Paulino-System UG & Altonaer Werbewerkstatt, Hamburg, Gemany) utilizes a separate ruler with 27 length-based weight categories for a body length from 44 to 151 cm and a color-coded booklet indicating drug doses,

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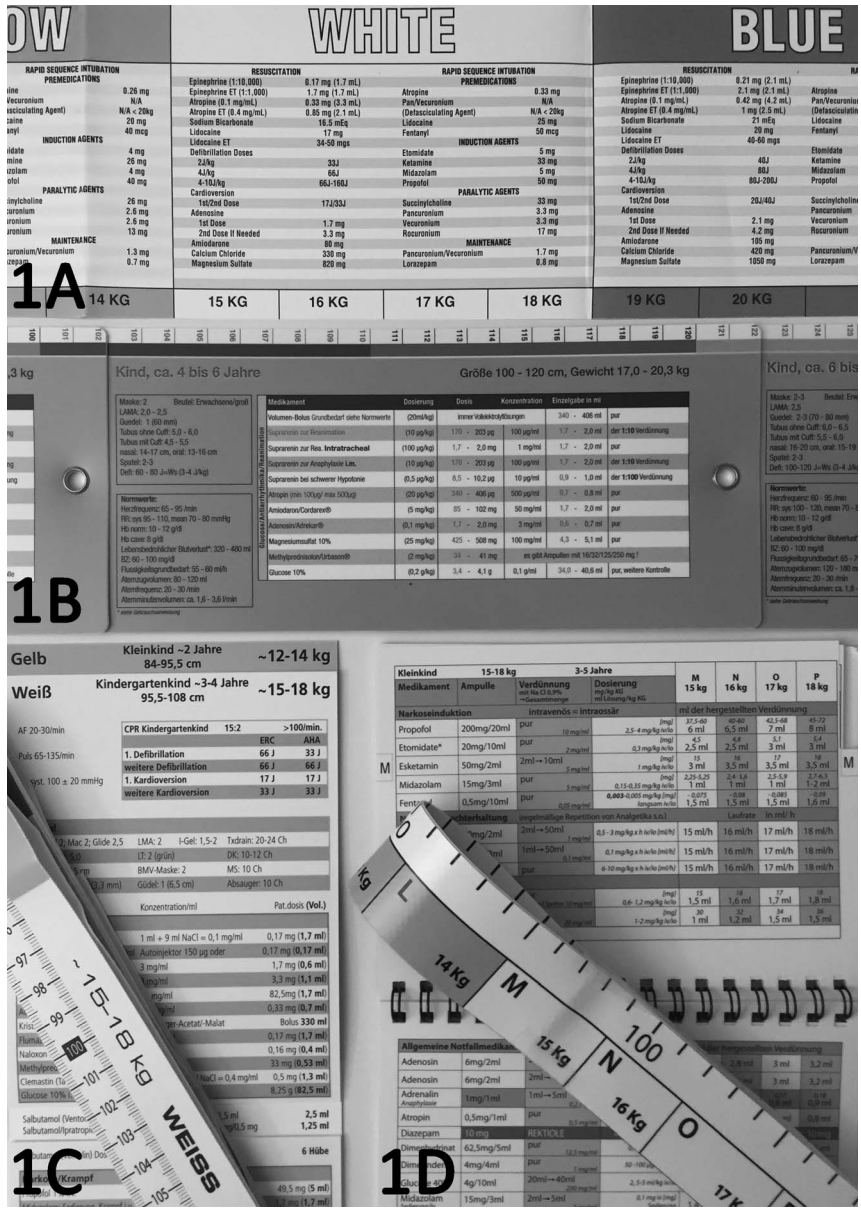


FIGURE 1. An excerpt of the Broselow Tape (A) and the Pädiatrisches Notfalllineal (B) showing 1 weight category (12–14 kg) for a body length of 80 to 100 cm and based on this the suggestions for drug dosing and medical equipment all printed on the pediatric emergency tape. The Kinder-Sicher (C) and the Paulino-System (D) use a separate ruler tape with length-based weight categories and color-coded groups. Drug dosing or selection of medical equipment suitable for the appropriate color-coded groups is provided in the separate flipchart booklet.

sizes of medical equipment, and vital parameters for each of the 27 weight categories.

Patients with a body length from 44 cm to 151 cm were included into the study allowing evaluation of the accuracy in each of the 4 emergency tapes with their specific length range. The primary outcome was the proportion of patients with an estimated body weight within ±10% as well as ±20% of measured body weight. Secondary outcome measures were the relative and absolute deviation of estimated from measured body weight as well as the incidence of underestimation and overestimation of body weight. Age stratification was conducted for every 1 year to investigate in which age interval the tapes have their strength and weakness.

Patient data as well as body weight estimation by the 4 pediatric emergency tapes were recorded in Microsoft Excel 2013 (Microsoft Corporation, Redmond, Wash) and compared using SPPS (IBM SPSS Statistics 22.0, Armonk, NY). Data are given as median (interquartile range [IQR]; range [min–max]) or as count (percent). Wilcoxon and McNemar tests were applied. Using Bonferroni correction due to multiple testing, a P value of less than 0.0125 was considered to indicate statistical significance.

RESULTS

From 23.940 patients recorded during the study period in the anesthesia PDMS, 12.557 patients met the inclusion criteria. From these, 3307 were identified with complete data sets (age, sex,

TABLE 1. Proportion of Patients With an Estimated Body Weight Within ± 10% and ± 20% of Measured Body Weight Displayed as Count (Percent).

	BT (n = 3038)	PNL (n = 2981)	PS (n = 3307)	KS (n = 3038)
Weight estimation in				
+/- 10% interval: count (%)	1642 (54.0)	1506 (50.5)	1649 (49.9)	1463 (48.2)
p-value		p < 0.001*	p = 0.856	p = 0.016
+/- 20% interval: count (%)	2477 (81.5)	2380 (79.8)	2581 (78.0)	2355 (77.5)
p-value		p = 0.003*	p = 0.032	p = 0.344

*McNemar and Bonferroni correction, a *P* value < 0.0125 is considered to indicate statistical significance.

weight, and length) and were within the specific length range of at least one of the emergency tapes (Table 1).

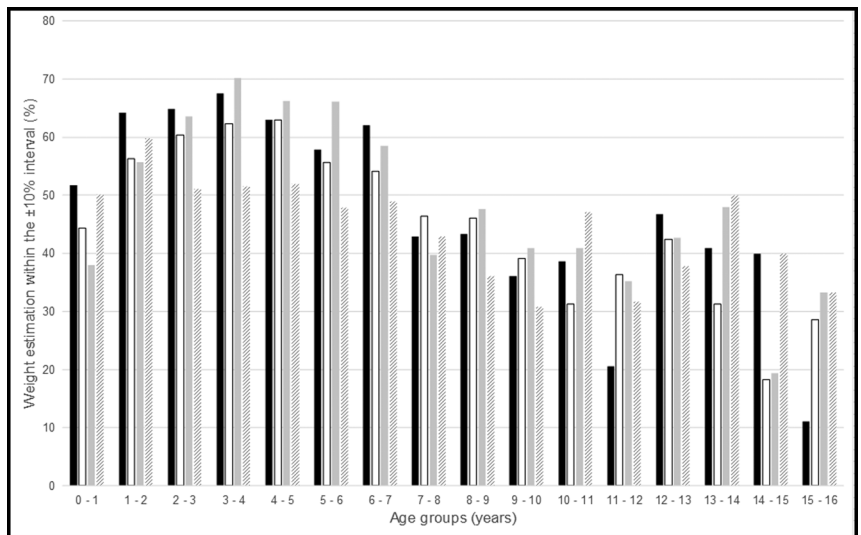
Of the 3307 patients eligible, 1930 (58.4%) were male and 1377 (41.6%) were female. Median patient age was 4.1 years (1.1–8.2; 16.0 [0.00–16.0]), median patient length was 101.0 cm (74.0–126.0; 107.0 [44.0–151.0]), and median patient weight was 15.8 kg (9.2–25.0; 75.5 [2.0–77.5]).

Proportion of length-based weight estimation within the ±10% and the ±20% interval was the highest in the BT with 54.0% and 81.5%, followed by the PNL, PS, and KS (Table 1). The incidence of weight estimation within the ±10% interval after age stratification is shown in Figure 2. Relative and absolute deviations of estimated from measured body weight are shown in Table 2.

The PS showed least cases of underestimation of body weight with 34.3% followed by the BT (36.8%), KS (38.9%), and PNL (41.5%). Pädiatrisches Notfalllineal, however, showed the lowest incidence of body weight overestimation with 55.5%, followed by KS (57.0%), BT (58.0%), and PS (61.3%) (Table 3).

DISCUSSION

This retrospective study compared the accuracy of 4 pediatric emergency tapes with different weight categories for length-based weight estimation. The main finding was that the BT has the highest proportion of weight estimations within the ±10% interval, followed by the PNL, the PS, and finally the KS.



BT	757	341	313	204	208	180	229	184	180	169	119	63	45	22	15	9
PNL	774	341	313	204	208	180	229	183	178	153	96	55	33	16	11	7
PS	774	341	313	204	208	180	229	184	185	186	176	125	103	48	36	15
KS	757	341	313	204	208	180	229	184	180	169	119	63	45	22	15	9

FIGURE 2. Incidence (%) of weight estimation within the ±10% interval after age stratification in to 16 groups. Table shows number of patients for each age group and emergency tape based on tape-specific length range.

TABLE 2. Absolute (kg) and Relative (%) Deviation of Estimated From Measured Body Weight

	BT	PNL	PS	KS
	(n = 3038)	(n = 2981)	(n = 3307)	(n = 3038)
Deviation of estimated weight, kg				
Mean (SD)	2.1 (2.9)	2.1 (2.9)	2.4 (3.5)	2.3 (3.0)
Median (IQR)	1.1 (0.5–2.5)	1.2 (0.5–2.5)	1.3 (0.6–2.8)	1.3 (0.5–3.0)
Range (min–max)	34.7 (0.0–34.7)	33.7 (0.0–33.7)	37.5 (0.0–37.5)	33.7 (0.0–33.7)
Deviation of estimated weight (%)				
Mean (SD)	12.1 (11.1)	12.9 (11.5)	13.3 (12.0)	13.6 (11.8)
Median (IQR)	9.2 (4.3–16.7)	10.0 (4.4–18.0)	10.1 (4.6–18.8)	10.5 (5.0–18.9)
Range (min–max)	104.1 (0.0–104.1)	93.9 (0.0–93.9)	122.2 (0.0–122.2)	104.1 (0.0–104.1)

This is the first study comparing 4 pediatric emergency tapes with different weight categories and also the first one publishing data about the PS and KS. With respect to the BT and PNL, the findings are in accordance to previously published studies.[10–12,16–18]

The present data show that more weight categories do not consistently result in a better weight estimation, because the overall performance of the PNL with 11 weight categories is indeed inferior compared with the BT (26 weight categories) but statistically equal to the PS with 27 weight categories. The results, however, indicate a higher accuracy for patients from 2 to 7 years of age when using emergency tapes with more weight categories (PS and BT, Table 4). These have a higher incidence of weight estimation within the ±10% interval for the aforementioned age range (Fig. 2). What all emergency tapes have in common is that their performance decreases in patients with an age of 7 years and older, showing less than 50% of estimations within the ±10% interval (Fig. 2). In addition, the performance of the BT needs to be critically scrutinized, because it estimates weight with 26 weight categories but suggests drug dosing based on only 11 weight categories, which results in the same accuracy than the KS.

The shortage of space on the emergency tape BT shows the limitations of the ruler-based systems, not allowing to transfer the estimated weight for recommendation of drug dosing. Both the KS and PS have a tape for weight estimation with color-coded groups and a separate booklet displaying drug dosing or medical equipment suitable for the appropriate color-coded group (Fig. 1), allowing more information due to more space. The PS even implements all 27 weight categories from the tape to the booklet, which unfortunately does not result in the best accuracy. In addition, the solution with a separate tape and booklet bears the risk of mistakes in stressful pediatric emergency situations.

The emergency tape BT was investigated by Heyming et al[19] comparing paramedic's weight estimation using BT on site with weight estimation in the emergency department by the emergency physician (resident or attending) using the BT, showing a difference of 29.4% (Cohen κ coefficient of 0.74 [95% confidence interval, 0.68–0.79]) regarding the conformity of the color zones. The performance would unlikely be better if the tape and information is apart, and medical equipment or drug dosing needs to be looked up in a separate booklet.

In conclusion, the accuracy of all 4 emergency tapes is poor, particularly in patients with an age of 7 years and older. The accuracy for weight estimation among the 4 tapes is best in the BT, followed by the PNL, the PS, and the KS. More weight categories do not necessarily increase accuracy of weight estimation. Other tools and/or techniques have to be developed to improve weight and age estimation in pediatric emergency situation without known patient data.

TABLE 3. Incidence of Underestimation and Overestimation of Body Weight Displayed in Count (percent).

	PS (n = 3307)	**BT** (n = 3038)	**KS** (n = 3038)	**PNL** (n = 2981)
underestimated weight: count (%)	1133 (34.3)	1117 (36.8)	1183 (38.9)	1236 (41.5)
	p < 0.001*	p = 0.002*	p = 0.005*	
	PNL (n = 2981)	**KS** (n = 3038)	**BT** (n = 3038)	**PS** (n = 3307)
overestimated weight: count (%)	1655 (55.5)	1733 (57.0)	1763 (58.0)	2028 (61.3)
	p = 0.08	p = 0.173	p < 0.001*	

*McNemar and Bonferroni correction, a *P* value < 0.0125 is considered to indicate statistical significance.

TABLE 4. Proportion of Patients with an Estimated Body Weight Within ± 10% of Measured Body Weight after Age Stratification Between 2 and 7 Years of Age.

	PS	BT	PNL	KS
Weight estimation in +/- 10% interval: count (%)	733 (65.6)	718 (63.3)	671 (59.2)	571 (50.4)
p-value		p = 0.155	p = 0.004*	p < 0.001*

N = 1134, displayed as count (percent).

*McNemar and Bonferroni correction, a *P* value < 0.0125 is considered to indicate statistical significance.

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